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(54) **DOUBLE ROTATION TYPE SCROLL
EXPANDER AND POWER GENERATION
APPARATUS INCLUDING SAME**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

801,182 A * 10/1905 Oreux 418/142
4,192,152 A * 3/1980 Armstrong et al. 62/402
4,990,071 A * 2/1991 Sugimoto 418/55.2

(Continued)

FOREIGN PATENT DOCUMENTS

JP 6341381 A 12/1994
JP 06341381 A * 12/1994 F04C 18/02

(Continued)

OTHER PUBLICATIONS

English Translation of JP H06-341381 (Dec. 1994).*

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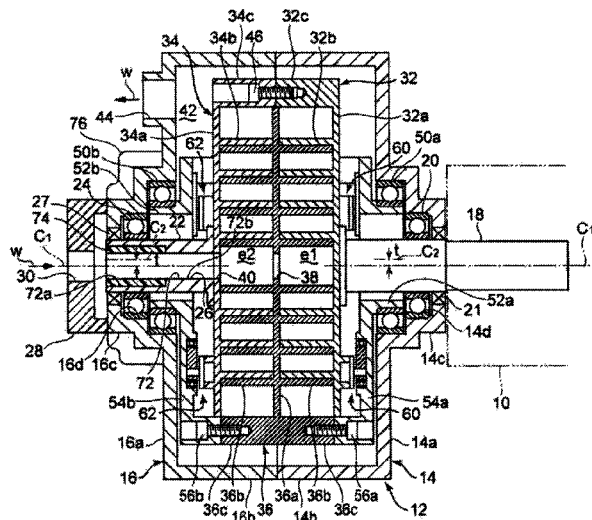
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(57) **ABSTRACT**

A double rotation type scroll expander that expands steam includes a first drive scroll, a second drive scroll, a driven scroll, a rotation mechanism that supports the driven scroll rotatably, and a revolving mechanism that couples the driven scroll to the first drive scroll and the second drive scroll to be capable of revolving relative thereto. The revolving mechanism includes: a plurality of metal revolving pins provided respectively between a first drive end plate of the first drive scroll and a first driven arm of the rotation mechanism and between a second drive end plate of the second drive scroll and a second driven arm of the rotation mechanism; and a plurality of metal revolving discs provided in relation to the respective revolving pins and disposed such that respectively corresponding revolving pins are coupled thereto eccentrically.

4 Claims, 2 Drawing Sheets



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(56)

References Cited

2007/0212245 A1 * 9/2007 Tsuchiya 418/55.3

U.S. PATENT DOCUMENTS

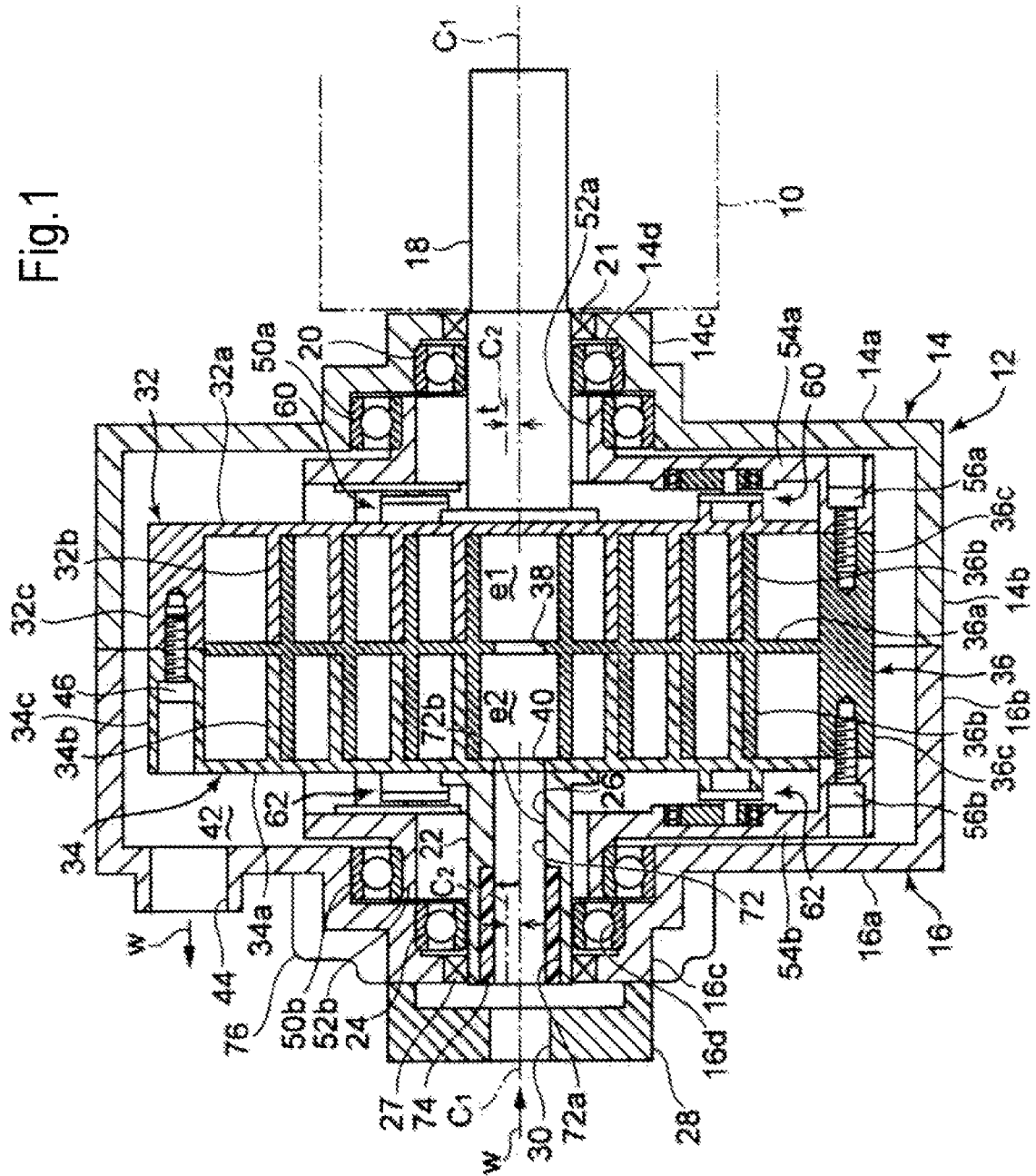
5,024,589 A * 6/1991 Jetzer et al. 418/55.3
5,318,425 A * 6/1994 Jetzer et al. 418/55.6
6,953,330 B1 * 10/2005 Muto 418/60
7,124,585 B2 * 10/2006 Kim et al. 60/643
2006/0216180 A1 * 9/2006 Yanagisawa et al. 418/55.2

FOREIGN PATENT DOCUMENTS

JP 2003269101 A * 9/2003 F01C 1/02
JP 2009209706 A 9/2009

* cited by examiner

Fig.1



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DOUBLE ROTATION TYPE SCROLL EXPANDER AND POWER GENERATION APPARATUS INCLUDING SAME

RELATED APPLICATIONS

The present application is based on, and claims priority from, Japanese Application Number JP 2012-100022, filed Apr. 25, 2012, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a double rotation type double wrap scroll expander in which two drive scrolls and a driven scroll rotate synchronously, and a power generation apparatus including this scroll expander.

2. Description of the Related Art

Conventional power generation systems tend mostly to be large scale plants generating at least several hundred kW, while small scale power generation is performed mostly by simply structured engine power generators and the like. Recently, however, due to increased awareness of the need for energy conservation, passage of the Act on Special Measures Concerning Procurement of Renewable Electric Energy by Operators of Electric Utilities, and the like, a need and a market for small scale power generation are gradually increasing.

Under these circumstances, photovoltaic generation and wind force power generation are not sufficiently cost-effective, and further improvements are required to reach a level at which general use is feasible.

Japanese Patent Application Publication No. 2009-209706, meanwhile, discloses a binary power generation system exhibiting relatively favorable cost-effectiveness. This binary power generation system includes a scroll expander and a power generator, and is configured such that a working medium having a low boiling point is pressurized to high pressure using hot water or steam at 85 to 150° C. as a heat source, whereupon the working medium is expanded by the scroll expander in order to drive the small scale power generator.

Here, a scroll expander exhibits little torque variation and is therefore suitable for use in a small scale power generation system. In a scroll expander having a fixed scroll and a drive scroll, however, the drive scroll slidably contacts with the stationary fixed scroll, and therefore a dynamic seal is required, making it difficult to secure a favorable sealing property. Further, a thrust load is exerted on the drive scroll, and therefore a bearing that supports the drive scroll rotatably is easily damaged.

A scroll fluid apparatus disclosed in Japanese Patent Application Publication No. H6-341381, on the other hand, is a double rotation type double wrap scroll fluid machine. With this type of scroll fluid machine, a favorable sealing property is obtained and the thrust load is reduced, leading to improved reliability.

More specifically, a double rotation type scroll fluid machine includes a drive scroll and a driven scroll, wherein the drive scroll and the driven scroll rotate synchronously. Hence, a dynamic seal is not required, and therefore a favorable sealing property can be secured. Further, when a double wrap scroll fluid machine is used as an expander, expansion chambers exist on both sides of the driven scroll, and there-

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fore a thrust load exerted on the drive scroll and the driven scroll is reduced by being canceled out.

SUMMARY OF THE INVENTION

In the scroll fluid machine disclosed in Japanese Patent Application Publication No. H6-341381, an Oldham ring is used as a revolving mechanism that causes the driven scroll to revolve relative to the drive scroll. However, an Oldham ring is typically made of resin, and therefore has low heat resistance. Hence, when a load is exerted on the Oldham ring in a high-temperature water vapor environment, the Oldham ring deforms. When high-temperature water vapor is expanded by a scroll expander using an Oldham ring, therefore, the revolving motion of the driven scroll may be obstructed by the deformation of the Oldham ring, possibly leading to a reduction in output or a breakdown.

The present invention has been designed in consideration of these problems in the prior art, and an object thereof is to provide a double rotation type scroll expander having high heat resistance, and a power generation apparatus including the double rotation type scroll expander.

To achieve this object, according to an aspect of the present invention, a double rotation type scroll expander that expands steam includes: a housing having an inflow hole into which the steam flows, a first end wall provided with a first shaft hole, and a second end wall provided with a second shaft hole that is coaxial with the first shaft hole; a first drive shaft that extends so as to penetrate the first shaft hole and has an inner end within the housing; a first drive bearing provided between the housing and the first drive shaft; a second drive shaft that is provided in the housing coaxially with the first drive shaft such that a part thereof is disposed inside the second shaft hole, and that includes a second inner end removed from a first inner end of the first drive shaft, and a connecting hole opened in the second inner end so as to communicate with the inflow hole; a second drive bearing provided between the housing and the second drive shaft; a first drive scroll including a first drive endplate coupled to the first inner end of the first drive shaft, and a first drive wrap projecting from an opposite side of the first drive end plate to the first drive shaft; a second drive scroll including a second drive end plate that is coupled to the second inner end of the second drive shaft and includes a drive through hole communicating with the connecting hole, and a second drive wrap projecting from an opposite side of the second drive end plate to the second drive shaft;

a driven scroll that includes a driven end plate disposed between the first drive wrap and the second drive wrap and provided with a driven through hole in a center thereof, and driven wraps projecting from respective surfaces of the driven end plate, and that forms an expansion chamber for expanding the steam on each side of the driven end plate in cooperation with the first drive scroll and the second drive scroll; a drive coupling member that couples the first drive scroll and the second drive scroll to each other integrally and rotatably; a rotation mechanism that includes a first driven boss and a second driven boss respectively disposed to surround the first drive shaft and the second drive shaft eccentrically to the first drive shaft and the second drive shaft, a first driven arm and a second driven arm extending respectively from the first driven boss and the second driven boss in respective radial directions of the first driven boss and the second driven boss, a first driven coupling member and a second driven coupling member respectively coupling the first driven arm to the driven scroll and the second driven arm to the driven scroll, and a first driven bearing and a second driven bearing provided respec-

tively between the housing and the first driven boss and between the housing and the second driven boss, whereby the rotation mechanism supports the driven scroll rotatably; and a revolving mechanism that includes a plurality of metal revolving pins provided respectively between the first drive end plate and the first driven arm and between the second drive end plate and the second driven arm, and a plurality of metal revolving discs provided in relation to the respective revolving pins and disposed such that respectively corresponding revolving pins are coupled thereto eccentrically, whereby the revolving mechanism couples the driven scroll to the first drive scroll and couples the driven scroll to the second drive scroll to be capable of revolving relative thereto.

In the double rotation type scroll expander according to this aspect, the revolving pins and revolving discs of the revolving mechanism are made of metal and therefore highly heat-resistant. Hence, the double rotation type scroll expander has a long lifespan even when used to expand water vapor, for example. Further, the driven scroll revolves smoothly relative to the first drive scroll and the second drive scroll, and therefore a rotary force output to the outside from the first drive shaft is increased.

Moreover, in this double rotation type scroll expander, the revolving pins couple the first drive scroll to the first driven arm and the second drive scroll to the second driven arm to be capable of a relative revolving motion. In other words, the revolving mechanism is provided on both the first drive scroll side and the second drive scroll side. The driven scroll is guided by the revolving mechanism on each side so as to revolve smoothly relative to the first drive scroll and the second drive scroll, whereby the rotary force output to the outside from the first drive shaft is increased.

Furthermore, in this double rotation type scroll expander, the expansion chamber is provided on both sides of the driven end plate of the driven scroll, and therefore an amount of inflowing steam can be increased, whereby the output rotary force can be increased, and a thrust load can be prevented from acting on the rotation mechanism and the revolving mechanism.

The double rotation type scroll expander described above may further include an adiabatic layer provided between the second drive bearing and an inner peripheral surface of the connecting hole.

According to this configuration, even when high-temperature steam flows through the connecting hole provided in the second drive shaft, a flow of heat from the connecting hole to the second drive bearing is impeded by the adiabatic layer, and therefore an increase in a temperature of the second drive bearing is suppressed, whereby a reliability of the second drive bearing is improved, leading to a further increase in the lifespan of the double rotation type scroll expander.

Further, to achieve the aforesaid object, according to an aspect of the present invention, a power generation apparatus includes: the double rotation type scroll expander described above; and a power generator coupled to the first drive shaft.

The double rotation type scroll expander used in this power generation apparatus exhibits great durability even when used to expand water vapor, for example, and generates a large output. Hence, the power generation apparatus can generate power efficiently using steam from water or the like, and is therefore highly cost-effective.

The present invention provides a double rotation type scroll expander having high heat resistance, and a power generation apparatus that includes this double rotation type scroll expander.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic longitudinal sectional view of a scroll expander according to an embodiment of the present invention; and

FIG. 2 is a partially enlarged view showing an enlargement of a revolving mechanism shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the present invention will be described in detail below with reference to the drawings. Note, however, that unless specific description is provided to the contrary, dimensions, materials, shapes, relative arrangements, and the like of constituent components described in the embodiment are not intended to limit the scope of the present invention.

FIG. 1 is a schematic longitudinal sectional view of a scroll expander according to an embodiment. The scroll expander is a double rotation type double wrap scroll expander that outputs a rotary force by expanding a high-pressure working medium *w*. The scroll expander is capable of expanding water, a refrigerant, and the like as the working medium *w*, and is therefore suitable for expanding high-temperature steam. The scroll expander is particularly suitable for expanding high-temperature water vapor having a temperature of approximately 170° C. to 180° C., for example. The water vapor may be superheated steam or saturated steam. The scroll expander is connected to a power generator 10 shown by a dot-dot-dash line in FIG. 1, and together with the power generator 10 constitutes a power generation apparatus. In the power generation apparatus, the scroll expander drives the power generator 10 using the working medium *w* as a power source, thereby causing the power generator 10 to generate power.

The scroll expander includes a substantially cylindrical housing 12, and the housing 12 is constituted by a first casing 14 and a second casing 16. The first casing 14 and the second casing 16 include, respectively, a first end wall 14a and a second end wall 16a, which are substantially circular, and a first peripheral wall 14b and a second peripheral wall 16b, which are substantially cylindrical and formed integrally with the first end wall 14a and the second end wall 16a, respectively. Respective tip ends of the first peripheral wall 14b and the second peripheral wall 16b are connected to each other in an airtight fashion such that a hollow space is defined inside the housing 12 by the first casing 14 and the second casing 16.

Stepped cylindrical portions 14c, 16c are provided integrally in respective centers of the first end wall 14a and the second end wall 16a, and the cylindrical portions 14c, 16c respectively define a first shaft hole 14d and a second shaft hole 16d penetrating the first end wall 14a and the second end wall 16a.

A first drive shaft 18 is provided to penetrate the first shaft hole 14d. The first drive shaft 18 is supported by a first drive bearing 20, disposed between the first drive shaft 18 and the cylindrical portion 14c, to be capable of rotating about an axis C₁ of the first drive shaft 18 and the first drive bearing 20. The first drive shaft 18 includes an inner end (a first inner end) positioned inside the housing 12 and an outer end positioned outside the housing 12, and the power generator 10 is connected to the outer end of the first drive shaft 18.

A sealing member 21 is disposed in a gap between an inner peripheral surface of an outer end of the cylindrical portion 14c and an outer peripheral surface of the first drive shaft 18, and the gap is made airtight by the sealing member 21.

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A second drive shaft 22 is provided coaxially with the first drive shaft 18. The second drive shaft 22 extends through the inside of the housing 12, and includes an inner end (a second inner end) positioned on the first drive shaft 18 side and an outer end positioned inside the cylindrical portion 16c. The second drive shaft 22 is supported rotatably by a second drive bearing 24 disposed between the second drive shaft 22 and the cylindrical portion 16c. The second drive bearing 24 is disposed coaxially with the first drive bearing 20 such that, similarly to the first drive shaft 18, the second drive shaft 22 is supported to be capable of rotating about the axis C_1 .

A connecting hole 26 is formed in the second drive shaft 22. The connecting hole 26 penetrates a radial direction central portion of the second drive shaft 22 in an axial direction, and opens onto an inner end surface and an outer end surface of the second drive shaft 22.

A sealing member 27 is disposed in a gap between an inner peripheral surface of an outer end of the cylindrical portion 16c and an outer peripheral surface of the second drive shaft 22, and the gap is made airtight by the sealing member 27.

A cover 28 is attached to the outer end of the cylindrical portion 16c in an airtight fashion, and an inflow hole 30 is formed in a center of the cover 28. The inflow hole 30 penetrates the cover 28, and is disposed coaxially with the connecting hole 26. The cover 28 forms a part of the housing 12 together with the first casing 14 and the second casing 16.

A first drive scroll 32, a second drive scroll 34, and a driven scroll 36 are disposed between the inner end of the first drive shaft 18 and the inner end of the second drive shaft 22.

The first drive scroll 32 and the second drive scroll 34 respectively include a first drive endplate 32a and a second drive endplate 34a, which are substantially circular. The inner end of the first drive shaft 18 and the inner end of the second drive shaft 22 are fixed integrally and rotatably to respective centers of the first drive endplate 32a and the second drive endplate 34a. Note that respective normal directions of the first drive endplate 32a and the second drive endplate 34a are parallel to the axis C_1 .

A first drive wrap 32b and a second drive wrap 34b are respectively provided integrally with the first drive end plate 32a and the second drive end plate 34a. The first drive wrap 32b projects integrally from an inner surface of the first drive end plate 32a on an opposite side to the first drive shaft 18, while the second drive wrap 34b projects integrally from an inner surface of the second drive endplate 34a on an opposite side to the second drive shaft 22.

In other words, the first drive end plate 32a and the second drive end plate 34a oppose each other via a predetermined interval, and the first drive wrap 32b projects from the first drive end plate 32a toward the second drive end plate 34a while the second drive wrap 34b projects from the second drive end plate 34a toward the first drive end plate 32a. A tip end of the first drive wrap 32b and a tip end of the second drive wrap 34b are separated from each other by a predetermined interval.

The driven scroll 36 includes a substantially circular driven end plate 36a. The driven end plate 36a is positioned between the tip end of the first drive wrap 32b and the tip end of the second drive wrap 34b such that the tip end of the first drive wrap 32b and the tip end of the second drive wrap 34b slidingly contact with respective surfaces of the driven end plate 36a.

Driven wraps 36b project integrally from the respective surfaces of the driven end plate 36a, and tip ends of the driven wraps 36b are respectively in sliding contact with the inner surface of the first drive end plate 32a and the inner surface of the second drive end plate 34a.

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When seen from the axial direction of the first drive shaft 18 and second drive shaft 22, the first drive wrap 32b, the second drive wrap 34b, and the driven wraps 36b have a spiral, or in other words an involute, planar shape, and are disposed such that the first drive wrap 32b intermeshes with the driven wrap 36b and the second drive wrap 34b intermeshes with the driven wrap 36b.

The first drive wrap 32b and the second drive wrap 34b have an identical spiral shape, and therefore overlap each other when seen from the axial direction of the first drive shaft 18. Similarly, the driven wraps 36b on the respective sides of the driven end plate 36a have an identical spiral shape, and therefore overlap each other when seen from the axial direction of the first drive shaft 18.

As a result, a first expansion chamber e1 is formed between the first drive scroll 32 and the driven scroll 36, and a second expansion chamber e2 is formed between the second drive scroll 34 and the driven scroll 36. In other words, the first drive scroll 32, the second drive scroll 34, and the driven scroll 36 cooperate with each other to form the first expansion chamber e1 and the second expansion chamber e2 on respective sides of the driven end plate 36a.

Capacities of the first expansion chamber e1 and the second expansion chamber e2 are at a minimum when the first expansion chamber e1 and the second expansion chamber e2 are positioned in a radial direction center of the driven end plate 36a, and increase gradually as the first expansion chamber e1 and the second expansion chamber e2 are respectively divided into two crescent-shaped pockets so as to extend outward in the radial direction of the driven end plate 36a along an inner surface and an outer surface of the driven wraps 36b.

A driven through hole 38 is formed in the center of the driven end plate 36a coaxially with the second drive shaft 22. The first expansion chamber e1 and the second expansion chamber e2 communicate with each other via the driven through hole 38 when positioned on the axis C_1 of the second drive shaft 22, or in other words when positioned centrally in the radial direction of the driven end plate 36a.

Further, a drive through hole 40 is formed in a center of the second drive end plate 34a coaxially with the second drive shaft 22, and the driven through hole 40 communicates with the connecting hole 26. Hence, the second expansion chamber e2 communicates with the inflow hole 30 via the connecting hole 26 and the drive through hole 40 when positioned centrally in a radial direction of the second drive end plate 34a. At this time, the first expansion chamber e1 is positioned centrally in the radial direction of the driven end plate 36a so as to communicate with the second expansion chamber e2 via the driven through hole 38, and therefore communicates with the inflow hole 30 via the second expansion chamber e2.

Upon reaching an outer peripheral portion of the driven end plate 36a, the first expansion chamber e1 and the second expansion chamber e2 communicate with a surrounding space 42 surrounding the first drive scroll 32, the second drive scroll 34, and the driven scroll 36 within the housing 12.

An outflow hole 44 is formed in the second end wall 16a of the second casing 16, and the surrounding space 42 communicates with the exterior of the housing 12 via the outflow hole 44.

A first outer peripheral portion 32c and a second outer peripheral portion 34c of the first drive wrap 32b and the second drive wrap 34b, which are positioned on respective outer peripheral sides of the first drive scroll 32 and the second drive scroll 34, are formed to be thicker than inner peripheral sides. The first outer peripheral portion 32c and the second outer peripheral portion 34c are coupled to each other

by a drive coupling screw 46. The drive coupling screw 46 is a coupling member that couples the first drive scroll 32 and the second drive scroll 34 to each other integrally and rotatably.

As a result, the first drive shaft 18, the first drive scroll 32, the second drive scroll 34, and the second drive shaft 22 are coupled integrally and coaxially, and supported rotatably on both sides by the first drive bearing 20 and the second drive bearing 24 sandwiching the first drive scroll 32 and the second drive scroll 34.

The driven scroll 36 is capable of rotating synchronously with the first drive scroll 32 and the second drive scroll 34, but a rotation center of the driven scroll 36 is removed from a rotation center of the first drive shaft 18 and the second drive shaft 22 by a predetermined distance in the radial direction of the driven end plate 36a.

The driven scroll 36 is also capable of revolving relative to the first drive scroll 32 and the second drive scroll 34 while rotating synchronously with the first drive scroll 32 and second drive scroll 34.

More specifically, a rotation mechanism that supports the driven scroll 36 to be capable of synchronous rotation includes a first rotation unit and a second rotation unit sandwiching the driven scroll 36.

The first rotation unit includes a first driven bearing 50a, a first driven boss 52a, a first driven arm 54a, and a first driven coupling screw 56a, while the second rotation unit includes a second driven bearing 50b, a second driven boss 52b, a second driven arm 54b, and a second driven coupling screw 56b.

The first driven boss 52a and the second driven boss 52b take a cylindrical shape and are surrounded respectively by the cylindrical portion 14c and the cylindrical portion 16c. The first driven bearing 50a and the second driven bearing 50b, which are constituted by roller bearings, are disposed respectively between the first driven boss 52a and the cylindrical portion 14c and between the second driven boss 52b and the cylindrical portion 16c. The first driven bearing 50a and the second driven bearing 50b are disposed coaxially.

Hence, the first driven boss 52a and the second driven boss 52b are supported by the first driven bearing 50a and the second driven bearing 50b to be capable of rotating about an axis C_2 of the first driven bearing 50a and the second driven bearing 50b. The axis C_2 is parallel to the axis C_1 but removed from the axis C_1 by a predetermined distance (an eccentricity amount) t .

The first driven arm 54a and the second driven arm 54b are provided integrally with the first driven boss 52a and the second driven boss 52b, respectively, so as to extend from the first driven boss 52a and the second driven boss 52b outward in a radial direction.

Outer peripheral portions 36c of the respective driven wraps 36b, which are positioned on an outer peripheral side of the driven scroll 36, are formed to be thicker than an inner peripheral side. The outer peripheral portions 36c are coupled to the first driven arm 54a and the second driven arm 54b, respectively, by the first driven coupling screw 56a and the second driven coupling screw 56b. In other words, the first driven coupling screw 56a is a coupling member that couples the first driven arm 54a to the driven scroll 36 integrally and rotatably, while the second driven coupling screw 56b is a coupling member that couples the second driven arm 54b to the driven scroll 36 integrally and rotatably.

Further, a revolving mechanism that causes the driven scroll 36 to revolve relative to the first drive scroll 32 and the second drive scroll 34 includes a plurality of first revolving units 60 provided between the first drive scroll 32 and the first rotation unit and a plurality of second revolving units 62

provided between the second drive scroll 34 and the second rotation unit. For example, three first revolving units 60 are provided at equal circumferential direction intervals around the first drive shaft 18, and three second revolving units 62 are provided at equal circumferential direction intervals around the second drive shaft 22.

FIG. 2 shows an enlargement of one of the first revolving units 60 shown in FIG. 1. The first revolving unit 60 includes a metal columnar revolving pin 63. An axis C_3 of the revolving pin 63 extends in parallel with the axis C_1 of the first drive shaft 18.

Meanwhile, a cylindrical recess 64 that opens onto the first drive end plate 32a is formed in the driven arm 54a of the first rotation unit, and the recess 64 is defined by a cylindrical peripheral surface 64a and an end surface 64b. A disc-shaped revolving disc 66 is disposed in the recess 64 concentrically therewith, and a thickness of the revolving disc 66 is approximately identical to a depth of the recess 64. A revolving bearing 68 constituted by a metal roller bearing is disposed between an outer peripheral surface of the revolving disc 66 and the peripheral surface 64a of the recess 64. The revolving disc 66 is capable of rotating within the recess 64 about an axis C_4 passing through a center thereof, which is parallel to the axis C_1 of the first drive shaft 18.

A pin insertion hole 66a is provided in the revolving disc 66, and the pin insertion hole 66a penetrates the revolving disc 66 in a thickness direction in a position removed from the axis C_4 in the radial direction. One end of the revolving pin 63 on the driven arm 54a side is press-fitted into the pin insertion hole 66a such that the revolving pin 63 is coupled eccentrically to the revolving disc 66 provided in relation to the revolving pin 63. When the revolving disc 66 rotates, the revolving pin 63 revolves about the axis C_4 of the revolving disc 66.

Meanwhile, a cylindrical boss portion 70 that opens toward the driven arm 54a is formed integrally with the first drive end plate 32a. Another end of the revolving pin 63 on the first drive end plate 32a side is formed as a large-diameter end portion 63a having a larger diameter than the one end side, and a collar portion 63b is formed integrally with the revolving pin 63 adjacent to the large-diameter end portion 63a.

The large-diameter end portion 63a of the revolving pin 63 is press-fitted into the boss portion 70 such that the collar portion 63b contacts a tip end of the boss portion 70, whereby the revolving pin 63 is fixed integrally to the boss portion 70. Thus, the boss portion 70 is capable of revolving about the axis C_4 of the revolving disc 66, whereby the driven scroll 36 is capable of revolving relative to the first drive scroll 32.

The axis C_3 of the revolving pin 63 is parallel to the axis C_4 of the revolving disc 66 but removed from the axis C_4 by a predetermined distance (an eccentricity amount) t . The eccentricity amount t of the axis C_4 from the axis C_3 is identical to the eccentricity amount t of the axis C_2 from the axis C_1 .

The second revolving unit, apart from being provided between the second drive end plate 34a and the second driven arm 54b, is configured identically to the first revolving unit, and therefore description of the second revolving unit has been omitted.

Further, in a preferred aspect of this embodiment, an adiabatic layer is provided between the inner peripheral surface of the connecting hole 26, which serves as a flow passage for the working medium w , and the second drive bearing 24.

More specifically, a stepped axial direction through hole 72 is formed in the second drive shaft 22 such that the second drive shaft 22 has a large diameter inner peripheral surface 72a on the outer end side and a small diameter inner peripheral

eral surface **72b** on the inner end side. A cylindrical sleeve **74** made of resin, for example, is fitted/fixed to the large diameter inner peripheral surface **72a** integrally and concentrically, and a thickness of a wall of the sleeve **74** is equal to a difference between radii of the large diameter inner peripheral surface **72a** and the small diameter inner peripheral surface **72b**.

Hence, the inner peripheral surface of the connecting hole **26** is formed from an inner peripheral surface of the sleeve **74** and the small diameter inner peripheral surface **72b** of the axial direction through hole **72**, which together form a continuous surface not having a step, and the sleeve **74** functions as the adiabatic layer between the inner peripheral surface of the connecting hole **26** and the second drive bearing **24**.

In another preferred aspect of this embodiment, a plurality of radiator plates **76** are provided integrally with the outer peripheral surface of the cylindrical portion **16c**. The radiator plates **76** are disposed in a radial fashion around the cylindrical portion **16c**.

An operation of the scroll expander described above will now be described.

High-temperature, high-pressure superheated steam serving as the working medium **w** flows into the second expansion chamber **e2** through the inflow hole **30** and via the connecting hole **26** and the drive through hole **40**, and then flows into the first expansion chamber **e1** via the driven through hole **38**. A temperature of the superheated steam when flowing through the inflow hole **30** is between 170° C. and 180° C., for example.

The first drive scroll **32**, the second drive scroll **34**, and the driven scroll **36** are caused to move in conjunction by a pressure (an expansion force) of the working medium **w** such that the capacities of the first expansion chamber **e1** and the second expansion chamber **e2** increase.

More specifically, the first drive scroll **32** and the second drive scroll **34** rotate about the axis C_1 of the first drive shaft **18** and second drive shaft **22**. For each revolution of the first drive scroll **32** and the second drive scroll **34**, the driven scroll **36** rotates once about the axis C_2 of the first driven boss **52a** and second driven boss **52b** and revolves once about the axis C_4 of the revolving disc **66**.

As the capacities of the first expansion chamber **e1** and the second expansion chamber **e2** increase, the first expansion chamber **e1** and the second expansion chamber **e2** move outward when seen from the radial direction of the driven end plate **36a**. The first expansion chamber **e1** and the second expansion chamber **e2** eventually communicate with the surrounding space **42** such that the expanded low-pressure working medium **w** in the first expansion chamber **e1** and the second expansion chamber **e2** flows out to the exterior of the housing **12** through the surrounding space **42** and the outflow hole **44**. In the meantime, a rotary force of the first drive shaft **18**, generated by the expansion force of the working medium **w** in the first expansion chamber **e1** and the second expansion chamber **e2**, is input into the power generator **10**, whereby the power generator **10** generates power.

In the scroll expander according to the embodiment described above, the revolving pins **63** and the revolving discs **66** of the revolving mechanism are made of metal and therefore highly heat-resistant. Hence, the scroll expander has a long lifespan even when used to expand superheated steam. Further, the driven scroll **36** revolves smoothly relative to the first drive scroll **32** and the second drive scroll **34**, and therefore the rotary force output to the outside from the first drive shaft **18** is increased.

Moreover, in the scroll expander described above, the revolving pins **63** couple the first drive scroll **32** to the first

driven arm **54a** and the second drive scroll **34** to the second driven arm **54b** to be capable of a relative revolving motion. In other words, the revolving mechanism is provided on both the first drive scroll **32** side and the second drive scroll **34** side. The driven scroll **36** is guided by the revolving mechanism on each side so as to revolve smoothly relative to the first drive scroll **32** and the second drive scroll **34**, whereby the rotary force output to the outside from the first drive shaft **18** is increased.

Furthermore, in this scroll expander, the first expansion chamber **e1** and the second expansion chamber **e2** are provided on the respective sides of the driven end plate **36a** of the driven scroll **36**, and therefore an amount of inflowing superheated steam can be increased, whereby the output rotary force can be increased, and a thrust load can be prevented from acting on the rotation mechanism and the revolving mechanism.

Further, with this scroll expander, the driven scroll **36** revolves smoothly relative to the first drive scroll **32** and the second drive scroll **34**, and therefore gaps between the driven scroll **36** and the first drive scroll **32** and second drive scroll **34** can be kept extremely small at all times, whereby the scroll expander can be made oil free, and in this case, oil can be prevented from intermixing with the working medium **w**.

Moreover, in a preferred aspect of this embodiment, the adiabatic layer is provided so that even when the high-temperature superheated steam flows through the connecting hole **26** provided in the second drive shaft **22**, a flow of heat from the connecting hole **26** to the second drive bearing **24** can be impeded by the adiabatic layer. Hence, an increase in the temperature of the second drive bearing **24** can be suppressed, thereby preventing the second drive bearing **24** and grease sealed in the interior of the second drive bearing **24** from deteriorating, and therefore a shortening of the lifespan of the second drive bearing **24** and the grease can be prevented, whereby a reliability of the second drive bearing **24** is improved, and the lifespan of the scroll expander is increased even further.

Furthermore, in this embodiment, the adiabatic layer is formed from the sleeve **74** fitted to the large diameter inner peripheral surface **72a** of the through hole **72**, and no step exists between the inner peripheral surface of the sleeve **74** and the small diameter inner peripheral surface **72b**, whereby the working medium **w** flows smoothly through the connecting hole **26**.

Moreover, in a preferred aspect of this embodiment, the radiator plates **76** are provided around the cylindrical portion **16c** so that the heat of the cylindrical portion **16c** is discharged to the outside efficiently. Likewise in this case, an increase in the temperature of the second drive bearing **24**, which is disposed on an inner side of the cylindrical portion **16c**, can be suppressed, leading to an improvement in the reliability of the second drive bearing **24** and a further increase in the lifespan of the scroll expander.

In the power generation apparatus including the scroll expander according to this embodiment, the scroll expander exhibits great durability even when used to expand high-temperature water vapor, and generates a large output. Hence, the power generation apparatus can generate power efficiently using high-temperature water vapor, and is therefore highly cost-effective.

The present invention is not limited to the embodiment described above, and includes embodiments obtained by amending the above embodiment.

For example, the sleeve **74** serving as the adiabatic layer may be provided over an entire region of the connecting hole **26**. Further, a fluororesin such as polytetrafluoroethylene or

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another type of engineering plastic may be used as a material of the sleeve 74. Alternatively, a different type of metal from the second drive shaft 22 may be used. Moreover, a metallic cylindrical collar may be fitted to all or a part of an outer peripheral region of the second drive shaft 22 as the adiabatic layer.

On the other hand, as long as durability can be secured in the second drive bearing 24, the adiabatic layer and the radiator plates 76 do not necessarily have to be provided.

Furthermore, in the scroll expander, two members coupled to each other integrally may be constituted by a single, integrally molded member. Alternatively, an integrally molded member may couple separate members to each other.

The present invention provides a double rotation type double wrap scroll expander having high heat resistance, and a power generation apparatus including the scroll expander.

What is claimed is:

1. A double rotation type scroll expander configured to expand steam, the double rotation type scroll expander comprising:

a housing having an inflow hole into which the steam is flowable, a first end wall including a first shaft hole, and a second end wall including a second shaft hole that is coaxial with the first shaft hole;

a first drive shaft configured to extend so as to penetrate the first shaft hole and having an inner end within the housing;

a first drive bearing provided between the housing and the first drive shaft;

a second drive shaft provided in the housing coaxially with the first drive shaft such that a part thereof is disposed inside the second shaft hole, and including a second inner end removed from a first inner end of the first drive shaft, and a connecting hole opened in the second inner end so as to communicate with the inflow hole;

a second drive bearing between the housing and the second drive shaft;

a first drive scroll including a first drive end plate coupled to the first inner end of the first drive shaft, and a first drive wrap projecting from an opposite side of the first drive end plate to the first drive shaft;

a second drive scroll including a second drive end plate coupled to the second inner end of the second drive shaft and including a drive through hole communicating with the connecting hole, and a second drive wrap projecting from an opposite side of the second drive end plate to the second drive shaft;

a driven scroll including a driven end plate disposed between the first drive wrap and the second drive wrap and including a driven through hole in a center thereof, and driven wraps projecting from respective surfaces of

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the driven end plate, and forming an expansion chamber for expanding the steam on each side of the driven end plate in cooperation with the first drive scroll and the second drive scroll;

a drive coupling member that couples the first drive scroll and the second drive scroll to each other integrally and rotatably, for the driven scroll to revolve relative to the first drive scroll and the second drive scroll such that a rotary force output to the outside from the first drive shaft is increased;

a rotation mechanism including a first driven boss and a second driven boss respectively disposed to surround the first drive shaft and the second drive shaft eccentrically to the first drive shaft and the second drive shaft, a first driven arm and a second driven arm extending respectively from the first driven boss and the second driven boss in respective radial directions of the first driven boss and the second driven boss, a first driven coupling member and a second driven coupling member respectively coupling the first driven arm to the driven scroll and the second driven arm to the driven scroll, and a first driven bearing and a second driven bearing provided respectively between the housing and the first driven boss and between the housing and the second driven boss, in a manner that the rotation mechanism supports the driven scroll rotatably; and

a revolving mechanism including a plurality of metal revolving pins provided respectively between the first drive end plate and the first driven arm and between the second drive end plate and the second driven arm, and a plurality of metal revolving discs provided in relation to the respective revolving pins and disposed such that respectively corresponding revolving pins are coupled thereto eccentrically, in a manner that the revolving mechanism couples the driven scroll to the first drive scroll and couples the driven scroll to the second drive scroll to be capable of revolving relative thereto.

2. The double rotation type scroll expander according to claim 1, further comprising an adiabatic layer between the second drive bearing and an inner peripheral surface of the connecting hole.

3. A power generation apparatus, comprising:

the double rotation type scroll expander according to claim 1; and

a power generator coupled to the first drive shaft.

4. The power generation apparatus according to claim 3, wherein the double rotation type scroll expander further comprises an adiabatic layer between the second drive bearing and an inner peripheral surface of the connecting hole.

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